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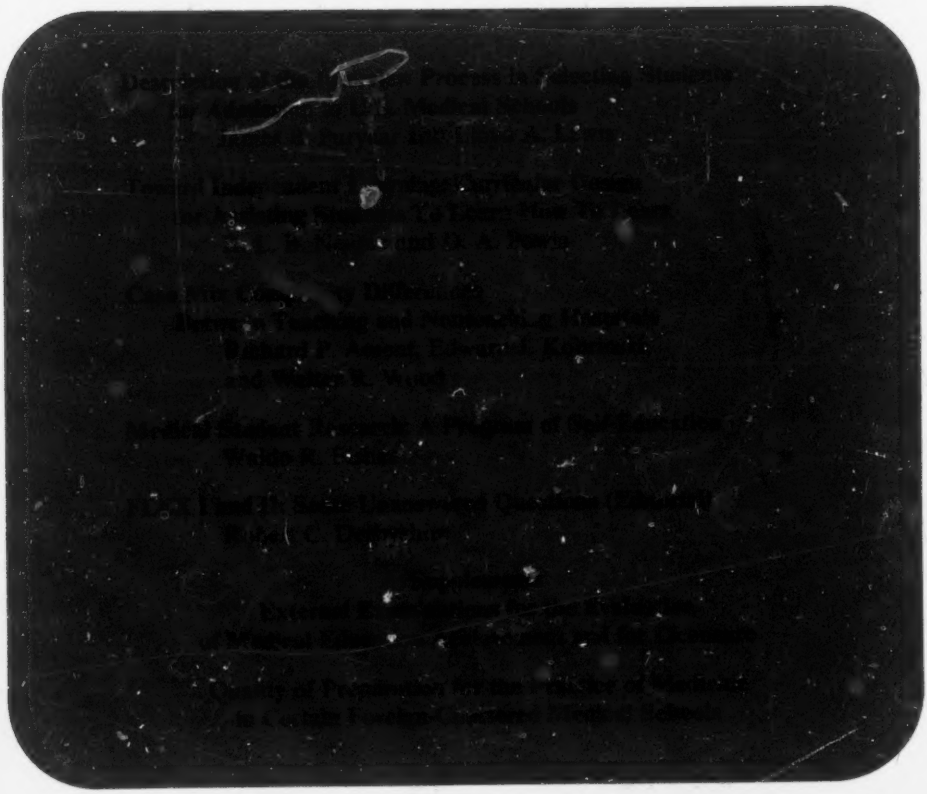

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Case Mix Complexity Differences Between Teaching and Nonteaching Hospitals

Richard P. Ament, Edward J. Kobrinski, and Walter R. Wood

Abstract—In the study reported here, the authors measured the differences between teaching and nonteaching hospitals in case mix complexity and provided some detail concerning the differences. They measured case complexity in a sample of 200 short-term general hospitals by the Resource Need Index (RNI) using a cross-classification of 3,490 case types with weights compiled from patient charges. Median RNI values were moderately higher for teaching than for nonteaching hospitals both for the hospital as a whole and for each clinical service except obstetrics-gynecology. The most resource-intensive case types were relatively more frequent in the teaching hospitals, but the least resource-intensive types were of about equal relative frequency in the two hospital groups. The results show that teaching hospitals could be expected to cost somewhat more per patient even if case mix were the only factor.

Several studies have concluded that patient mix is an important determinant of hospital costs. In a limited number of studies, diagnostic case mix variables have been explicitly introduced to explain variation in hospital costs (1–4).

But the literature provides little information on the case mix component of cost differentials between teaching and nonteaching hospitals. An early study of Lave and Lave related teaching status to various case mix indices (5), but the results could not be used quantitatively in explaining or justifying cost differences between teaching and nonteaching hospitals, because the weights used in their calculation only indirectly related to the costliness of the different case types. Two studies measured the contribution of case mix to the excess of average length of stay in teaching hospitals over that in nonteaching hospitals, but neither analyzed total costs nor accounted for the substantial expenses due to ancillary services. In the first study, hospitals with interns or residents had expected average stays that were in excess of those in nonteaching hospitals by 0.5 day for hospitals with 5,000 to 9,999 annual discharges, by 0.5 day for hospitals with 10,000 to 14,999 discharges, and by 0.2 day for hospitals with 15,000 or more discharges (6). In the second study, major teaching hospitals had longer expected average stays than other teaching hospitals by 0.4 day (7).

Two other studies used case mix measures reflecting total charges of patients in base data. A 1976 study of 76 hospitals participating in the "Study of Patient

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Charges" (SPC) of the Commission on Professional and Hospital Activities (CPHA), a medical records abstracting service, found statistically significant higher median case mix index values in hospitals with residents than in other hospitals (8). The Office of Research, Demonstrations, and Statistics of the U.S. Health Care Financing Administration used a 20 percent sample of the Medicare patient records for 1978 from some 5,600 hospitals to calculate for each hospital's Medicare patients an overall case mix measure. The researchers applied case-type weights representing national averages of Medicare patient bills adjusted for cross-subsidization, level of teaching activities, and local wage rates. Hospitals having a ratio of residents and interns to beds exceeding 0.25 had significantly higher values of the case mix measure than other hospitals.

One reason for the dearth of studies on case mix differences between teaching and nonteaching hospitals is that financial information on individual hospitalizations has seldom been merged with the medical record information needed to class patients into case types. The linkage of financial and medical information is made, however, in SPC data at the CPHA. The present study made use of this data base in obtaining weights, derived from patient charges, to represent the case complexity of the various case types. For each hospital, these weights were applied to the proportions of patients falling into the various case types to yield an index of case mix, the Resource Need Index (RNI) (2). The RNI was used in this study to test the hypotheses.

As previously stated, teaching hospitals, especially major teaching hospitals, presumably attract a mix of patients that intrinsically is relatively costly to treat. Therefore, it was hypothesized that the highest RNI values would be found in the major teaching hospitals, the next highest in the other teaching hospitals, and the smallest in the nonteaching hospitals. Since hospital size also has been thought to affect case mix, this hypothesis was examined separately for each of several size groups. To provide some detail in the expected findings, the analyses of hospital-wide RNI values were repeated by clinical service.

Because teaching hospitals are often considered referral hospitals that attract the hardest-to-treat patients, an additional hypothesis was that individual patients represented by very high case mix weights would be relatively more frequent in teaching hospitals than in nonteaching. A further hypothesis was that the patients with very low RNI values would be found with equal relative frequency in both sets of hospitals. Both of the foregoing hypotheses could be accepted if patients with RNI values in the middle range are admitted less frequently to the teaching hospitals. Again, detail was added by repeating these analyses in individual clinical services.

Methods

The resource needs of the hospitals were estimated by the RNI, which is a case mix complexity index displayed in the routine reports of the SPC (8) of the CPHA and which also is featured in ad hoc reports prepared for other hospitals that supply hospital discharge abstracts in which diagnoses and operations are coded in *H-ICDA*, *ICDA-8*, or *ICD-9-CM*. To define case types for this index, a cross-classification was used. Patients were first divided on the basis of principal diagnosis into the 349 groupings of the original CPHA List A: Hospital Diagnosis Groups (9). Each of the diagnosis groups was divided into two subgroups according to presence or absence of surgery, and each of these was split into five age ranges (or five birth weight groups for newborn patients).

Thus, 3,490 case types resulted. This classification is identical to that used in the series of books on length of stay statistics published by the CPHA, except that the CPHA books make a further split on presence or absence of secondary diagnoses.

The base for the RNI consists of charge norms (expected charges) for the 3,490 case types in the classification. The present study used the 1971–74 version of the base, compiled from 1.8 million patients from a changing cohort of approximately 50 hospitals that participated in the SPC during those years. These are self-selected nonfederal short-term general hospitals in the United States, representing a wide variation in size and location and including both teaching and nonteaching hospitals (8). Before the calculation of the charge weights, the actual charges were adjusted for local economic conditions and inflation.

The meaning of the RNI and its construction are explained as follows. One measure of a hospital's case mix complexity is the average total charge per patient that would have resulted if each patient's charge had been typical for that kind of patient, that is, had been equal to the norm or weight compiled for that kind of patient in base data. This measure may be called the average norm of total charge or the expected average charge and is computed by the formula

$$\sum_j P_{jk} W_j,$$

where P_{jk} is the proportion of patients in type j among all the patients in hospital k, and W_j is the norm of total charge for case type j in base data.

The RNI is simply the ratio of this quantity for hospital k to the corresponding quantity for the base data, that is, to the per-patient average norm of total charge in the base. For hospital k, then,

$$RNI_k = \sum_j P_{jk} W_j \Big/ \sum_j P_{j+} W_j,$$

where P_{j+} is the proportion of cases in case type j among all the patients in the base.

Thus, if hospital k has a mix of patients like that in the base, its RNI would be 1.00; if its mix is richer than usual in the kinds of patients that ordinarily incur high total charges, its RNI would be greater than 1.00. Since the RNI values calculated for this study excluded births, they tended to average a little higher than 1.00.

For this study, hospitals were drawn from a sampling frame consisting of all short-term nonfederal not-for-profit general hospitals that were enrolled in the CPHA's Professional Activity Study (PAS) for the entire year 1976 and that discharged enough births to account for at least 1 percent of their total patient volume. These hospitals were cross-classified by census region, hospital size, and teaching status. Total annual discharges were used as follows to define four hospital size groups: (*a*) medium-small hospitals: 5,000 to 9,999 annual discharges; (*b*) medium hospitals: 10,000 to 14,999 annual discharges; (*c*) medium-large hospitals: 15,000 to 19,999 annual discharges; and (*d*) large hospitals: 20,000 or more annual discharges.

For purposes of this study, three categories of hospital teaching status were used—major teaching, other teaching, and nonteaching. Major teaching hospitals had approved residencies (10) in at least three of the four specialties, internal medicine, obstetrics-gynecology, pediatrics, and surgery, or in at least two of them if the hospital did not serve patients in all four areas. The remaining hospitals were called other teaching hospitals if they had accredited residencies in at least one of the four specialties and nonteaching hospitals if they had no residencies in any of these specialties.

Within each combination of teaching status and size group, geographic balance was obtained by drawing the same number of hospitals from the sampling frame for

each region; the constant number drawn was the largest permitted by the sampling frame up to a maximum of 10.

A total of 200 U.S. hospitals enrolled in the PAS were selected in this way. For each hospital, the RNIs were calculated for the total hospital excluding newborn patients and, in addition, for five broad clinical services that together accounted for all patients. For comparability among hospitals, each patient's service was assigned by computer, using the computer program module whose routine use was to supply service categories to all patients in the PAS system for whom the hospital omitted this item from the case abstract.

For the hospital as a whole excluding newborn and for each service separately, RNI values were compared between hospital groups as follows: (*a*) teaching hospitals (major teaching and other teaching taken together) versus nonteaching hospitals, within size categories, and (*b*) major teaching hospitals versus other teaching hospitals, within size categories.

For hospitals that had at least 10 patients in the given category, median differences between RNIs were calculated using the Hodges-Lehmann estimator (11), and the statistical significance of these differences was tested by the Wilcoxon rank-sum test (11). These nonparametric techniques were chosen to maximize stability in the estimates and to minimize error in the statistical tests due to outliers.

The comparisons of RNIs were complemented by corresponding comparisons of distributions of patients according to their individual RNI values to determine whether case types that ordinarily incur high hospital bills tended to be concentrated in teaching hospitals.

Results

In all four size groups, teaching hospitals had slightly higher Resource Need Index values than nonteaching (Table 1); in two size groups the difference was statistically significant ($p < .05$) and in one nearly significant ($p = .052$). The difference was most pronounced among the largest hospitals and least pronounced among the smallest hospitals. But even in the largest size group, the median difference was under 10 percent.

Major teaching hospitals differed little

TABLE 1

Comparison of Hospital-Wide Resource Need Index (RNI) Values Between Teaching and Nonteaching Hospitals Participating in Professional Activity Study (PAS), 1976

Hospitals	No.	No. of Patients	Median RNI	Median Difference*	Significance Level (*p* value)†
Medium-Small					
Teaching	16	110,839	1.070	.029	.304
Nonteaching	40	254,574	1.029		
Medium					
Teaching	20	225,559	1.133	.056‡	.020
Nonteaching	40	452,785	1.079		
Medium-Large					
Teaching	40	643,185	1.132	.048	.052
Nonteaching	20	312,312	1.077		
Large					
Teaching	16	377,312	1.166	.093‡	.038
Nonteaching	8	169,160	1.067		

* Teaching minus nonteaching, calculated using the Hodges-Lehmann estimator.

† Determined by means of the Wilcoxon rank-sum test (two tails).

‡ Significant at the .05 level.

from other teaching hospitals with respect to RNI values (Table 2). In fact, major teaching hospitals actually had the smaller median RNIs in the two smallest size groups, although none of the differences were statistically significant. Major teaching hospitals showed a persistent increase in RNI from one size group to the next. The corresponding increase in RNI among the other teaching hospitals was neither as uniform nor as great.

There was a great overlap in the RNI distributions from one hospital group to another, as seen in Figure 1. For example, in the 800 possible pairs consisting of one teaching and one nonteaching hospital from the 40 teaching and 20 nonteaching hospitals in the medium-large size group, the teaching hospitals had a higher RNI value in only 68 percent of the pairs. There was an even greater degree of overlap between the two levels of teaching activity.

The broad clinical services of pediatric medicine, general medicine, general surgery, and newborn were represented by teaching-nonteaching differences in RNI values (Table 3) that crudely paralleled those found for the whole hospital's patients excluding births (Table 1) in that the differences were all positive and, except for newborn, were greater in the largest-size hospitals than in the smallest. Obstetrics-gynecology presented a different picture, however, with little teaching-nonteaching difference in RNI values at any size level.

Case types that require little resources were found in about the same proportions in all the hospital categories, as seen in the lower percentile lines in Figure 2. On the other hand, costly-to-treat case types were relatively much more abundant in teaching than in nonteaching hospitals. In fact, patients with individual RNI values over 2.00 were about a third again as abundant in the teaching as in the nonteaching hospitals. The exception to this rule is the medium-small hospitals, where the major teaching hospitals had slightly fewer of the high-resource patients than even the nonteaching hospitals. Within clinical services, the excess proportion of high RNI values for individual patients in teaching hospitals over those in nonteaching hospitals was most pronounced in the newborn service and in pediatric medicine, followed

TABLE 2

Comparison of Hospital-Wide Resource Need Index (RNI) Values Between Major Teaching and Other Teaching Hospitals Participating in PAS, 1976

Hospitals	No.	No. of Patients	Median RNI	Median Difference*	Significance Level (p value)†
Medium-Small					
Major	4	30,075	.943	−.130	.132
Other	12	80,764	1.076		
Medium					
Major	16	182,697	1.122	−.030	.616
Other	4	42,862	1.154		
Medium-Large					
Major	20	321,780	1.144	.010	.646
Other	20	321,405	1.104		
Large					
Major	8	199,217	1.198	.032	.506
Other	8	178,095	1.149		

* Major teaching minus other teaching, calculated using the Hodges-Lehmann estimator.

† Determined by means of the Wilcoxon rank-sum test (two tails).

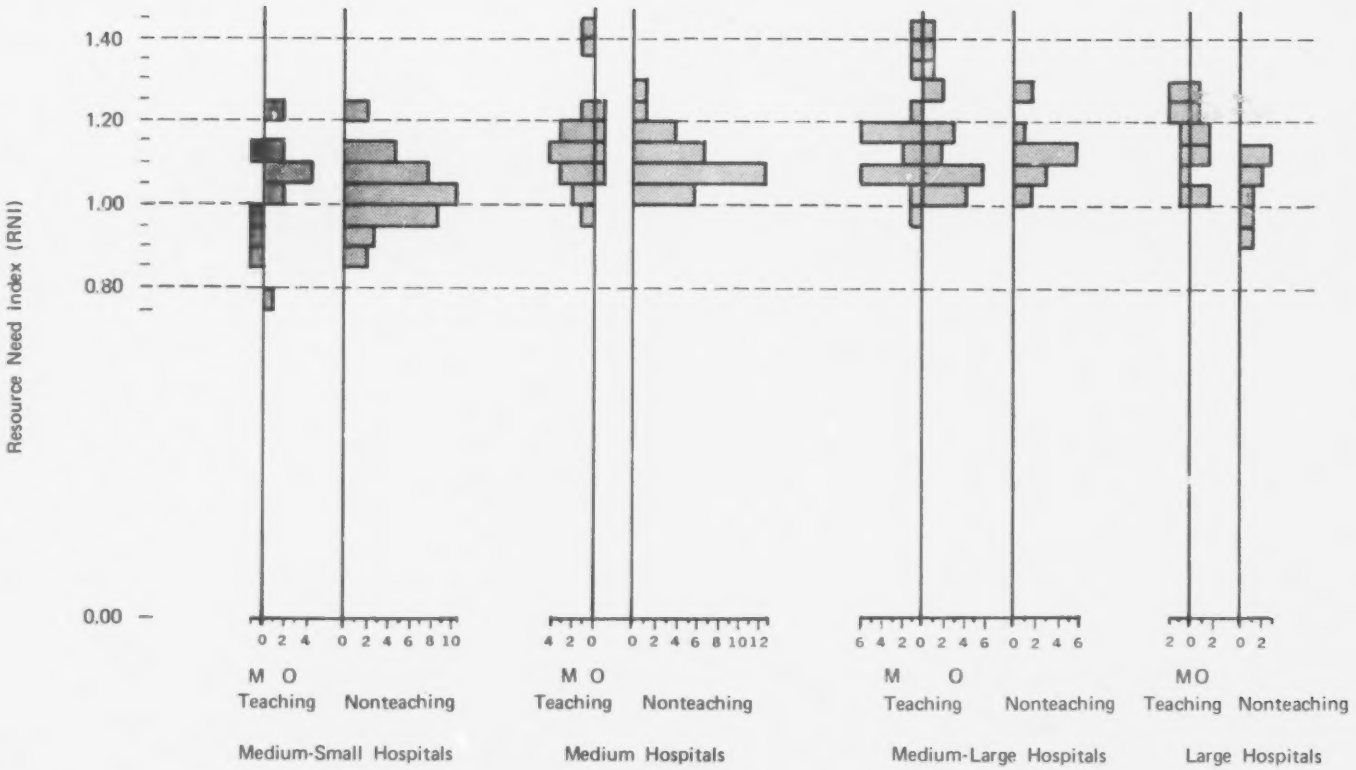

FIGURE 1

Distributions of hospital RNI values, by hospital size by teaching status (M = major teaching hospitals; O = other teaching hospitals).

TABLE 3

Comparison of Resource Need Index (RNI) Values Between Teaching and Nonteaching Hospitals by Clinical Service

Service/Hospital Size	Teaching Hospitals			Nonteaching Hospitals			Median Difference*	Significance Level (p value)†
	Median RNI	No.	Patients	Median RNI	No.	Patients		
Pediatric Medicine								
Medium-small	.644	3	1,000	.608	51	13,000	.066	.069
Medium	.630	9	7,000	.615	51	21,000	.027	.342
Medium-large	.669	14	13,000	.640	46	22,000	.024	.522
Large	.855	8	11,000	.652	16	11,000	.176‡	.004
General Medicine								
Medium-small	1.192	9	21,000	1.225	47	96,000	.001	.976
Medium	1.319	17	62,000	1.248	43	150,000	.068§	.020
Medium-large	1.348	28	136,000	1.273	32	148,000	.069‡	.006
Large	1.354	10	76,000	1.329	14	85,000	.043	.522
General Surgery								
Medium-small	1.136	13	37,000	1.121	43	117,000	.023	.528
Medium	1.279	18	88,000	1.172	42	219,000	.116‡	.002
Medium-large	1.279	34	253,000	1.180	26	185,000	.086‡	.006
Large	1.238	11	118,000	1.211	13	132,000	.056	.258
Obstetrics-Gynecology								
Medium-small	.657	5	13,000	.647	51	66,000	− .002§	.944
Medium	.638	15	38,000	.661	45	93,000	− .013‡	.418
Medium-large	.651	22	76,000	.668	38	121,000	− .011§	.318
Large	.685	14	70,000	.657	10	44,000	.005‡	.818
Newborn								
Medium-small	.247	3	2,000	.221	53	35,000	.042	.048
Medium	.258	9	12,000	.227	51	53,000	.031	.006
Medium-large	.241	14	24,000	.227	46	73,000	.013	.036
Large	.260	8	19,000	.225	16	41,000	.039	.001

* Teaching minus nonteaching, calculated using the Hodges-Lehmann estimator.

† Determined by means of the Wilcoxon rank-sum test (two tails).

‡ Significant at the .01 level.

§ Significant at the .05 level.

by general medicine and general surgery (data not shown). In obstetrics-gynecology, there was a slight contrast in the other direction. In all services, patients with the lowest RNI values had about the same relative frequency in teaching as in nonteaching hospitals.

Discussion

The RNI is a case mix index that expresses the average of case complexity weights that have been assigned to the patients according to their case types. Each weight, compiled from base data, represents the mean amount of resources used as reflected by patient total charges. A hospital that has a high average for the weights of its patients, that is, a high RNI value, may be said to have a complex case mix in the economic sense.

Two potential problems of a case mix measure built on total charges are (*a*) that charges do not perfectly reflect costs and (*b*) that for some applications a case mix measure should relate to direct costs instead of total costs. Evidence that these problems are not serious is found in a study of 316 short-term hospitals in the United States (12); the RNI correlated extremely high ($r = .97$) with a similar case

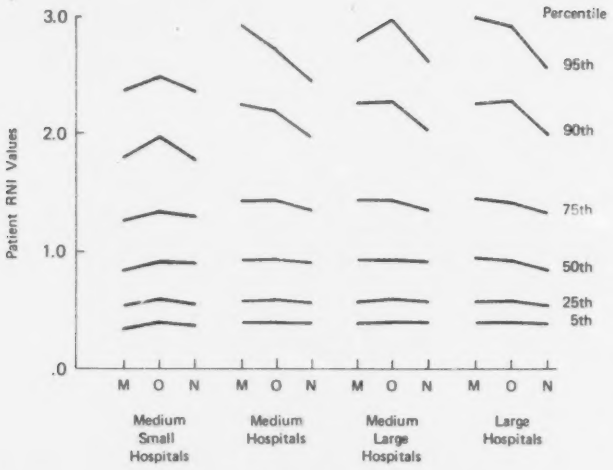

FIGURE 2
Percentile distributions of individual patients' RNI values, by hospital size by teaching status (M = major teaching hospitals; O = other teaching hospitals; N = nonteaching hospitals).

mix measure that used diagnosis related groups with New Jersey direct cost weights. The small difference between that correlation and perfect correlation (r = 1.00) is partly due to the double distinction between total charge and direct cost, but it also reflects differences between the data bases used for calculating the weights, between rules for excluding outlier patients, and between case-type classifications.

A third potential problem is that teaching-nonteaching differences in case mix index values could be partly due to the corresponding pricing and intensity differences and not simply to differences in the intrinsic costliness of the patients. For example, suppose that there were only two case types and that the average charge was $1,000 for each in nonteaching hospitals and $1,200 for each in teaching hospitals but that case type Y is relatively twice as frequent in teaching hospitals. Then the weight for case type Y would exceed that for case type X, and so the teaching hospitals would have a higher case mix index than the nonteaching hospitals. To avoid such spurious effects, individual patients' total charges were adjusted before being averaged across hospitals within case types to produce the weights for the RNI. The adjustment divisor for each half year's data for each hospital contributing to the weights was proportional to the ratio of the actual average charge to the RNI value calculated from weights compiled from earlier years' data. Since this adjustment was carried out each time new charge weights were compiled, the third generation weights used in this study would be almost completely free of the kind of distortion described above.

In any case, there appears to be no reason to suspect that comparisons among hospitals would be biased by the characteristics of the RNI statistic.

That the teaching-nonteaching differential in case mix complexity increased with hospital size is consistent with the concept of large teaching hospitals as being referral centers for patients whose care is difficult and costly. As might be expected, the same interaction was observed within

the teaching hospitals between size and teaching status in accounting for variations in RNI values; but the reverse direction of the difference in the two smaller-size groups seems surprising and needs further investigation.

The previously mentioned contrasts in hospital-wide RNI values between teaching and nonteaching hospitals were paralleled by similar contrasts within four of the five clinical services. The exception was that the teaching-nonteaching differences were not found in the obstetrics-gynecology service. An interpretation may be that only a small proportion of delivery cases are identified beforehand as being so difficult to manage as to influence the choice of hospitals.

The substantial teaching-nonteaching difference in proportions of patients with very high case mix weights contrasted with the lack of a corresponding difference for very low case mix weights. In any case, the distributions of case mix weights were not grossly dissimilar between the two groups in any of the clinical services. Evidently, routine case types requiring little resources are as well represented in teaching hospitals as in nonteaching hospitals. One would also surmise that the kinds of patients seen by medical students and residents closely resemble those they can expect to find in nonteaching hospital environments.

The economic impact of case mix complexity differences found in this study may be gauged by translating them into dollars. In 1981, for example, case mix alone should account for about $100 of the difference in average cost per case between teaching and nonteaching hospitals in the medium and medium-large size groups and $180 in the large size group. These figures were obtained by assuming that the respective RNI differences of about .05 and .09, found in this study, would hold true for 1981, for which a conservative estimate of average cost per case is $2,000. The latter figure is the approximate result of applying an annual growth factor of 11 percent to the $1,641 average adjusted expense per admission in community hospitals in 1979, as reported in *Hospital Statistics* (13). Thus, the extra expense burden of a medium-sized teaching hospital due to its more complex case mix is likely to exceed $1,000,000 a year. It is important, therefore, that reimbursement differentials for teaching hospitals make sufficient allowance for their heavier case mix.

Conclusion

Analysis using the RNI as a measure of case mix complexity revealed that the case mix in teaching hospitals on the average is intrinsically somewhat more resource intensive than the case mix in nonteaching hospitals, irrespective of the costs of the teaching or research functions or differences in the intensity of care provided to given kinds of patients. It follows that fair reimbursement of teaching hospitals should adequately compensate for their greater case mix complexity.

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